Lecture 7

Scene Graphs
Recall: Structure of a CUGL Application

Diagram showing the structure of a CUGL application with nodes for Main, Application, Active, Dormant, Scene, Models, Root Node.
## Recall: The Application Class

### `onStartup()`
- Handles the game assets
  - Attaches the asset loaders
  - Loads immediate assets
- Starts any global singletons
  - **Example**: AudioChannels
- Creates any player modes
  - But does not launch *yet*
  - Waits for assets to load
  - Like `GDXRoot` in 3152

### `update()`
- Called each animation frame
- Manages gameplay
  - Converts input to actions
  - Processes NPC behavior
  - Resolves physics
  - Resolves other interactions
- Updates the scene graph
  - Transforms nodes
  - Enables/disables nodes
### Recall: The Application Class

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<thead>
<tr>
<th><strong>onStartup()</strong></th>
<th><strong>update()</strong></th>
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| - Handles the game assets  
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  - Like `GDXRoot` in 3152  | - Called each animation frame  
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  - Converts input actions to engine actions  
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**onShutdown()** cleans this up

Does not draw! Handled separately
Drawing in CUCL

- Use the **draw()** method
  - Called after `update()`
  - Clears screen first
  - Uses clear color field
- Can use any OpenGL
  - Included in `CUBase.h`
  - Best to use OpenGL ES (subset of OpenGL)
- Or use a SpriteBatch
  - *Mostly* like in 3152

```c
void draw() {
    glEnableVertexAttribArray(0);
    glBindBuffer(GL_ARRAY_BUFFER, vertexbuffer);
    glVertexAttribPointer(0, 3, GL_FLOAT, GL_FALSE, 0, (void*)0);
    glDrawArrays(GL_TRIANGLES, 0, 3);
    glDisableVertexAttribArray(0);
}
```

```c
void draw() {
    batch->begin();
    batch->draw(image1, Vec2(10, 10));
    batch->draw(image2, Vec2(50, 20));
    batch->end();
}
```
The Scene Graph

Or any subclass

Scene

Node

Node

Node

Node

Node

Node

Node
The Scene Graph

Node

Bounded box inside

Game Camera

Node

Coords relative to parent box

Node

Node

Node

Node

Node

Node

Node

Node
Each Node is a Coordinate System
Each Node is a Coordinate System

Scene Root

Node

Node

Node

Node

Node

Scene

Node

Node

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Scene Graphs
Each Node is a Coordinate System

Scene Root

Node

Node

Node

Node

Origin

Origin

Origin

Scene Graphs
Motivation: Touch Interfaces

- Touch handler requires
  - Which object touched
  - Location inside object
- Scene graph is a *search tree*
  - Check if touch is in parent
  - … then check each child
  - Faster than linear search
- But limit this to a *search*
  - No input control in node
  - Use polling over callbacks
Settings Pass Down the Graph

Scene Root

Node
Node
Node
Transforms on parent also transform children
Settings Pass Down the Graph

Scene Root

Node

Node

Node

Transparency on parent also applies to children
Settings Pass Down the Graph

Disabling the parent also disables children
Anchors and Content

- Nodes have **content size**
  - Width/height of contents
  - Measured in node space
  - But only a guideline: content can be outside

- Nodes have an **anchor**
  - Location in node space
  - **Percentage** of width/height
  - Does not affect the origin

- Both may affect **position**
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Anchor and Position

Anchor: (0,0)
Position: (150,50)
Anchor and Position

Parent

Anchor: (0.5,0.5)
Position: (150,50)

Node

Child

Child

Origin
Layout Managers

- Not all devices have the same aspect ratio
- Sometimes, want placement to adjust to fit

Scene Graphs
Layout Managers

- Not all devices have the same aspect ratio
- Sometimes, want placement to adjust to fit
Layout Managers

- **AnchorLayout**
  - Node
  - Node
  - Node

- **FlowLayout**
  - Parent
  - Node
  - Node
  - Node

- **GridLayout**
  - Parent
  - Node
  - Node
  - Node
_layout Managers

AnchorLayout Floaout

GridLayout

See Documentation for Details

Scene Graphs
How to Use a Layout Manager

1. Create a layout manager

2. Assign a relative position to each child
   - **Example**: middle left in an anchor layout
   - Layout manager maps strings to layout
   - Use the “name” string of the child node

3. Attach manager to the parent node

4. Call `doLayout()` on the parent
Safe Area: Modern Phones

UI elements should avoid notch, rounded corners

But animations should fill screen
Safe Area: Modern Phones

Scene

Game Node

UI Node

Art that must fill the screen

Elements to stay in safe area

See Display class to find safe area
Rendering a Scene is Easy

- **scene->render(batch)**
  - Uses SpriteBatch to draw
  - Calls begin()/end() for you
  - Sets the SpriteBatch camera
  - Limits *in-between* drawing

- Uses a **preorder traversal**
  - Draws a parent node first
  - Draws children in order
  - Parent acts as background
How Does a SpriteBatch Work?

- Sprites = textured **triangles**
- Gather all sprite vertices
- Make one list of triangles
- Send them to GPU at once
- But stall on texture change
  - Reorder data on texture
  - Draw texture all at once
  - Limits texture switches
  - Safe if there is **no overlap**
- Hence the name!
How Does a SpriteBatch Work?

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Optimizing Performance: zOrder

- SpriteBatch defers to Scene
  - Scene determines order
  - Reordering a scene is bad
- Give *hints* to the Scene
  - Give each child a z-value
  - Ties are permitted
  - sortZOrder() sorts tree
  - Can make this automatic
- Controls *texture switching*
  - One texture = one z-value
  - Reduces it to one draw call
Optimizing Performance: **Atlases**

- **Idea**: Never switch textures
  - Film strip is many images
  - We can draw part of texture
  - One texture for everything?
  - Called a **texture atlas**

- **Disadvantages?**
  - Cannot tile textures
  - Can be tricky to pack

- **Ideal for **interface design**
  - Images for UX widgets
  - Often small and compact
Specialized Nodes

- CUGL has many node types
  - AnimationNode (animation)
  - WireNode (wireframes)
  - PolygonNode (tiled shapes)
  - PathNode (lines with width)
  - NinePatch (UI elements)
  - Label (text)

- Learn them outside of class
  - Read the documentation
  - Play with the demos
JSON Language for Scene Graphs

```
"textfield" : {
  "type"    : "Node",
  "format" : { "type" : "Anchored" },
  "children" : {
    "action" : {
      "type" : "TextField",
      "data" : {
        "font" : "felt",
        "text" : "Edit me",
        "size" : [600, 80],
        "anchor" : [0.5, 0.5]
      }
    },
    "layout" : {
      "x_anchor" : "center",
      "y_anchor" : "top"
    }
  }
}
```
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            }
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}
```
Each node has

- Type
- Format
- Data
- Children
- Layout

Scene Graphs
The Problem: **Physics**
The Problem: **Physics**

**How big is that scene graph?**
Defining Custom Nodes

<table>
<thead>
<tr>
<th><strong>draw()</strong></th>
<th><strong>generateRenderData()</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Overridden to render node</td>
<td>• Overridden to update cache</td>
</tr>
<tr>
<td>• Only node, not children</td>
<td>• Change vertex positions</td>
</tr>
<tr>
<td>• The <code>render</code> method (do not touch) handles children</td>
<td>• Change vertex colors</td>
</tr>
<tr>
<td>• Drawing data is <strong>cached</strong></td>
<td>• Change texture coordinates</td>
</tr>
<tr>
<td>• The vertex positions</td>
<td>• Only needed for <strong>reshaping</strong></td>
</tr>
<tr>
<td>• The vertex colors</td>
<td>• Transforms for movement</td>
</tr>
<tr>
<td>• The texture coordinates</td>
<td>• Called infrequently</td>
</tr>
<tr>
<td>• Cache passed to <code>SpriteBatch</code></td>
<td>• Optimizes the render pass</td>
</tr>
</tbody>
</table>
The **draw()** Method

```cpp
void CustomNode::draw(const std::shared_ptr<SpriteBatch>& batch,
   const Mat4& transform, Color4 tint) {

   if (!_rendered) {
      generateRenderData();
   }

   batch->setColor(tint);
   batch->setTexture(_texture);
   batch->setBlendEquation(_blendEquation);
   batch->setBlendFunc(_srcFactor, _dstFactor);

   batch->fill(_vertices, _vertsize, 0,
               _indices, _indxsie, 0,
               transform);
}
```
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                _indices, _indxsize, 0, 
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}
```

Computed from parent (+camera)

Computed from parent (+scene)

The Render Data
Summary

• CUGL tries to leverage ideas from 3152
  • Top level class works like the classic GDXRoot
  • Design architecture to switch between modes
  • Use SpriteBatch class to draw textures in 2D.

• New idea is using **scene graphs** to draw
  • Tree of nodes with relative coordinate systems
  • Makes touch input easier to process
  • Also helps with animation (later)

• New JSON language makes design easier